MAKING HARD DECISIONS

with *DecisionTools*®

3rd Edition

Now with
Darden Cases

ROBERT T. CLEMEN & TERENCE REILLY

Making Hard Decisions
with DecisionTools®

THIRD EDITION

Making Hard Decisions
with DecisionTools®

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To the memory of Ward Edwards,
whose work continues to inspire us.

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PREFACE

This book provides a one-semester overview of decision analysis for advanced undergraduate and master's degree students. The inspiration to write it has come from many sources, but perhaps most important was a desire to give students access to up-to-date information on modern decision analysis techniques at a level that could be easily understood by those without a strong mathematical background. At some points in the book, the student should be familiar with basic statistical concepts normally covered in an undergraduate applied statistics course. In particular, some familiarity with probability and probability distributions would be helpful in Chapters 7 through 12. Chapter 10 provides a decision-analysis view of data analysis, including regression, and familiarity with such statistical procedures would be an advantage when covering this topic. Algebra is used liberally throughout the book. Calculus concepts are used in a few instances as an explanatory tool. Be assured, however, that the material can be thoroughly understood, and the problems can be worked, without any knowledge of calculus.

The objective of decision analysis is to help a decision maker think hard about the specific problem at hand, including the overall structure of the problem as well as his or her preferences and beliefs. Decision analysis provides both an overall paradigm and a set of tools with which a decision maker can construct and analyze a model of a decision situation. Above all else, students need to understand that the purpose of studying decision-analysis techniques is to be able to represent real-world problems using models that can be analyzed to gain insight and understanding. It is through that insight and understanding—the hoped-for result of the modeling process—that making hard decisions can be improved.

NEW IN THIS EDITION

This revision has been a long time in the works, and we thank our readers for their patience. As you scan the book, we think you will agree that it has had a major overhaul, and we hope you find the result worth the wait.

The book has been thoroughly revised. Every chapter has been carefully rewritten and brought up-to-date, including new references where appropriate. Chapters 5, Sensitivity Analysis, and Chapter 11, Monte Carlo Simulation, have been completely rewritten. Jeff Guyse contributed material on behavioral decision theory in order to bring Chapters 8, 14, 15, and 16 up-to-date on behavioral issues in probability and utility assessment.

Perhaps the most noticeable additions are two new chapters contributed by Sam Bodily. Under his electronic pen, the previous Chapter 6 on Creativity has been transformed into a new chapter on Organizational Decision Making. He has also contributed the completely new Chapter 13 on Real Options.

Many of the examples, problems, and cases have been updated, and many new ones have been added. In particular, we are fortunate to be able to include 15 cases from Darden's extensive collection. We have grouped appropriate cases at the end of each of the three major sections of the book.

The Palisade DecisionTools Suite is the up-to-date version 6, and all of the tutorials and screen shots in the text have been updated to reflect the new software. It is our intention to modify the tutorials as needed in the future to keep abreast of changes and improvements that Palisade makes in the software.

Finally, you will discover two things missing. First, much of the material that was previously labeled "Optional" is no longer in the book, but available as online content. Three sections that were labeled optional in the previous edition are no longer optional: Constructing an Influence Diagram in Chapter 3; Two-Way Sensitivity Analysis for Three Alternatives in Chapter 5; and Decreasing and Constant Risk Aversion in Chapter 14. Second, the book no longer includes appendices containing pages of numbers for the various probability distributions. Between Microsoft Excel® and the Palisade software included with the book, probabilities for all of those distributions (and many more besides) can be easily found.

GUIDELINES FOR STUDENTS

Along with instructions on using the DecisionTools software, this version of *Making Hard Decisions* covers most of the concepts we consider important for a basic understanding of decision analysis. Although the text is meant to be an elementary introduction to decision analysis, this does not mean that the material is itself elementary. In fact, the more we teach decision analysis, the more we realize that the technical level of the math required for decision analysis is low, whereas the level of the analysis is high. Students must be willing to think clearly and analytically about the problems and issues that arise in decision situations. Good decision analysis requires clear thinking; sloppy thinking results in worthless analysis.

Of course, some topics are more demanding than others. As mentioned previously, for this edition a number of "optional" (i.e., more difficult) sections from previous editions are now available only as online supplements. Our faith in students and readers compels us to say that anyone who can handle the material in the new edition can, with a bit more effort and thought, also handle the online supplements.

In general, we believe that serious learning happens when one tackles problems on one's own. We have included a wide variety of exercises, questions, problems, and case studies. The exercises are relatively easy drills of the material. The questions and problems often require thinking beyond the material in the text. Some concepts are presented and dealt with only in the problems. Do not shy away from the problems! You can learn a lot by working through them.

Many case studies are included in *Making Hard Decisions*. A few of the many successful applications of decision analysis show up as case studies in the book. In addition, many issues are explored in the case studies in the context of current events. In addition to the real-world cases, the book contains many hypothetical cases and examples, as well as fictional historical accounts, all of which have been made as realistic as possible.

Some cases and problems are realistic, but not all the factual information is presented. In these cases, appropriate assumptions are required. On one hand, this may cause some frustration. On the other hand, incomplete information is typical in the real world. Being able to work with problems that are "messy" in this way is an important skill.

Finally, many of the cases and problems involve controversial issues. For example, the material on AIDS (Chapter 7) or medical ethics (Chapter 16) may evoke strong emotional responses from some readers. In writing a book like this, there are two choices: We can avoid the hard social problems that might offend some readers, or we can face these problems that need careful thought and discussion. The text adopts the second approach because we believe these issues require society's attention. Moreover, even though decision analysis may not provide the answers to these problems, it does provide a useful framework for thinking about the difficult decisions that our society must make.

A WORD TO INSTRUCTORS

Many instructors will want to supplement *Making Hard Decisions* with their own material. In fact, topics that we cover in our own courses are not included here. But, in the process of writing the book and obtaining comments from colleagues, it has become apparent that decision-making courses take on many different forms. Some instructors prefer to emphasize behavioral aspects, whereas others prefer analytical tools. Other dimensions have to do with competition, negotiation, and group decision making. *Making Hard Decisions* does not aim to cover everything for everyone. Instead, we have tried to cover the central concepts and tools of modern decision analysis with adequate references (and occasionally cases or problems) so that

instructors can introduce their own material where appropriate. For example, in several places we discuss judgmental aspects of probability assessment and decision making, and an instructor can introduce more behavioral material at these points. Similarly, Chapter 16 delves into the additive utility function for decision making. Some instructors may wish to present goal programming or the analytic hierarchy process here.

Regarding the DecisionTools software, we wrote the instructions as a self-contained tutorial. Although the tutorial approach works well, we also believe that it must be supplemented by guidance from the course instructor. One possible way to supplement the instructions is to walk the students through the instructions in a computer lab. This will allow the instructor to answer questions as they arise and will allow students to learn the software in a controlled environment. No new material need be prepared for the computer-lab session, and in the text the students have a written copy of the instructions for later reference.

KEEPING UP WITH CHANGES

The world changes quickly, and decision analysis is changing with it. The good news is that the Internet helps us keep abreast of new developments. We encourage both students and instructors to visit the website of the Decision Analysis Society at www.informs.org/Community/DAS. This organization provides a focus for decision analysts worldwide and many others with interests in all aspects of decision making. On the Society's web page you will find links to many related resources and websites.

While you are keeping up with changes, we hope that you will help us do the same. Regarding the software or instructions in using the software, please send your comments to Terence Reilly at reilly@babson.edu. For all other non-software matters, please send comments to either Terence Reilly or Robert Clemen at clemen@duke.edu. Please send information about (hopefully the few) mistakes or typos that you may find in the book, innovative ways to teach decision analysis, new case studies, or interesting applications of decision analysis.

INSTRUCTOR RESOURCES

Instructor's Resource and Solutions Manual

The Instructor's Resource and Solutions Manual contains teaching notes, a topical cross reference for problems, and answers to all exercises, questions, problems and case studies, including the Darden cases. This supplement is available for convenient download for instructors only at http://login.cengage.com.

PowerPoint® Slides

Exceptional new PowerPoint slides have been created specifically for this edition by Patrick Wheeler at the University of South Florida. Liven up your classroom with engaging PowerPoint slides that contain an excellent summary of each chapter, numerous examples, figures and lively animation. You can modify or

customize the slides for your specific course. PowerPoint slides are available for convenient download for instructors only at http://login.cengage.com.

ADDITIONAL SUPPLEMENTS FOR BOTH STUDENTS AND INSTRUCTORS

Chapter Supplements

Due to the variance in how instructors teach the course, many additional supplements will be made available online for students and instructors. All online materials for students can be found at www.cengagebrain.com. Instructors can access the materials at http://login.cengage.com. Online supplemental reading materials include:

Chapter 4: Solving Influence Diagrams: The Details

Chapter 6: Blocks to Creativity and Additional Creativity Techniques

Chapter 7: Correlation and Covariance for Measuring Dependence

Chapter 8: Coherence and the Dutch Book

Chapter 10: Natural Conjugate Distributions

Chapter 17: Three or More Attributes

In addition to the above, data sets and selected Excel models from each chapter can be found at www.cengagebrain.com.

Palisade's DecisionTools Suite, 6.0

The DecisionTools Suite is an integrated set of programs for risk analysis and decision making under uncertainty that runs in Microsoft Excel. The DecisionTools Suite includes @RISK for Monte Carlo simulation, PrecisionTree for decision trees and influence diagrams, StatTools for statistical analysis and forecasting, and RISKOptimizer for stochastic optimization. The programs work together better than ever before, and all integrate completely with Microsoft Excel for ease of use and maximum flexibility. The programs are backward compatible, with models created under older versions seamlessly updated to version 6.0. Additional resources, such as example models and instructional videos are available at www.palisade.com. With purchase of the book, students have complimentary access to the software at www.cengagebrain.com.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the help we have had with the preparation of this text.

First mention goes to our students, who craved the notes from which the text has grown. For resource support, thanks to the institutions that have supported our work on this and previous editions: The Lundquist College of Business at the University of Oregon; Decision Research of Eugene, Oregon; Applied Decision Analysis, Inc., of Menlo Park, California; the Fuqua School of Business of Duke University; Babson College; and the Board of Research at

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Introduction to Decision Analysis

Have you ever had a difficult decision to make? If so, did you wish for a straightforward way to keep all of the different issues clear? Did you end up making the decision based on your intuition or on a "hunch," but wondered if you were leaving out important details? Although difficult decisions are a common fact of life, understanding how to rigorously analyze decisions is not so common. Rigorous analysis is not as daunting as it sounds and provides unique and helpful insights that can greatly clarify the decision. This chapter introduces decision analysis, a process that provides a structured method with analytical tools designed to improve one's decision-making skills.

The introduction opens with a contentious decision faced by the Board of Regents of Rice University about the status of their college football program. For those who don't know, Rice is located in the state of Texas, a state known for passionate football allegiances and rivalries.

Don't Mess with Texas Football	In 2004, The Board of Regents of Rice University knew that something had to be done about their costly football program. They also knew that their actions would be closely scrutinized by various groups, and unpopular but fiscally sound measures could spark a firestorm of protests. At the center of the decision sat a $4 million deficit, an amount that was expected to grow and that Rice could ill afford year after year. On the one hand, the problem was simple enough: Rice's Board had a fiduciary responsibility to reduce the football program's sizable deficit. On the other hand, football's value extended beyond simple cost accounting to include important, but intangible benefits, such as boosting school spirit and pride, improving alumni relations, and supporting local businesses. Thus, the Board needed to understand and preserve the value of these intangible benefits to the school while coming up with cost-cutting proposals. Throw in the intense emotions

surrounding college football, and Rice's Board was indeed facing a hard decision.

Part of the problem—but also a source of pride—was the fact that Rice was the smallest university in Division I-A, the most prestigious division of the NCAA (National Collegiate Athletics Association). Not all Division I-A schools are created equal, and Rice was discovering that size does matter. For example, ticket receipts of other Division I-A schools averaged $6.5 million annually, whereas Rice could only expect a paltry $900,000. Also, Rice received little of its revenues from the highly profitable bowl games. Although Rice spent $18.4 million annually on athletics, placing them in the lower half of spending by Division I-A schools, they spent the most per undergraduate student at $6,809, more than four times the median spending per student at other Division I-A schools. Clearly, the Board had to address these financial difficulties, but what were their options?

An interesting option that the Board considered was to drop out of Division 1-A, and move to a lower division. They viewed Division III as a better alternative than Division II because the universities belonging to Division III, such as University of Chicago, New York University, and Carnegie Melon were on par with Rice academically. The expectation was that Division III would be lower cost, Rice would gain prestige by association, and, for the student athletes, the emphasis would move toward academic achievement and away from the nearly professional status of many collegiate-sports programs.

While changing divisions held some promise, it was also controversial. Fans, supporters, and alumni formed an advocacy group called Friends of Rice Athletics. They argued through a letter-writing campaigns and rallies that not every university program had to make a profit. They cited an NCAA report claiming that less than a dozen football programs nationwide generated more revenue than costs. Why should Rice's program be required to meet a standard so few other schools met?

Clearly, Rice's Board of Regents faced a particularly complex problem. They could not lightly dismiss the years of support by fans and alumni, nor could they ignore the annual $4 million deficit. Before deciding exactly what course of action to take, the Board needed to carefully consider and balance many issues, including the values of the different constituent groups—but how? There is no escaping the problem: This hard decision requires hard thinking. Add to this complex mix the inherent uncertainty in the situation regardless of the action they took, and you can see the need for clarity and insight when making hard decisions.

The good news is that decision analysis adds clarity and insight in several ways. First, it provides a conceptual framework for thinking systematically

through hard decisions. For example, decision analysis allows us to break the problem down into smaller, more easily understood pieces that can be analyzed individually. Second, decision analysis supplies analytical tools that lead to insights and a deeper understanding of the problem. For example, sensitivity analysis tells us which inputs are most important and hence deserve our time and attention. Decision analysis not only helps with our decisions, but instills a sense of confidence in actions we choose.

The bad news is that decision analysis cannot make hard decisions easy. The fact is that hard decisions are just that–hard. Decision analysis is not a magic wand; we cannot simply feed our inputs into a computer and expect the answer to pop out. We must think through all the various aspects of the decision, often from competing viewpoints. We still need to think about all future events and their resulting consequences. While a decision maker can take action with confidence earned through a clear understanding of the issues, this comes only from doing the work needed to find the insights and understand the issues.

WHY ARE DECISIONS HARD?

What makes decisions hard? Viewed from the perspective of a specific decision, each problem is unique and carries its own special difficulties. With experience, however, we begin to see the uniqueness disappear. What looked special in one case may turn out to be a common difficulty across many problems. For example, while Rice's Board was in the unique position of having to balance financial responsibilities with the interests of the fans, alumni, and boosters, they were actually facing the more general problem of decision making with multiple and competing objectives. It is worthwhile to understand how our own unique decision fits into a broader picture, because doing so will help us choose appropriate tools for analysis and may lead us to examine how others have solved similar problems.

Four broad sources of difficulty commonly appear: complexity, uncertainty, multiple objectives, and competing viewpoints. Decision analysis can help with all four.

First, a decision can be hard simply because of its complexity. In the case of Rice's football program, the Board of Regents must consider many different issues: reducing the deficit, balancing the opposing values of the various stakeholders, understanding the value of intangible benefits such as school pride, and so on. In addition, there is uncertainty; no matter what the Board of Regents might decide, future events beyond their control could result in good or bad consequences for the school. Complexity can quickly overwhelm a decision maker, making it nearly impossible to guarantee that each critical component of the decision is appropriately considered in the analysis.

A powerful aspect of decision analysis is its ability to reduce complexity. We will see many examples in which decision analysis picks off pieces one-by-one in a complex problem, allowing the decision maker to think hard about each piece. Although investigating isolated parts of the problem simplifies it, doing so runs the risk of ignoring important connections or relationships between the pieces. Thus, after carefully thinking through the individual pieces, we reassemble them into an overall structure. For example, we will see how to use decision trees and influence diagrams to structure and analyze decisions and to answer "what if" questions. These tools provide effective methods for organizing a complex problem into a structure that can be analyzed.

Second, a decision can be difficult because of the inherent uncertainty in the situation. In a situation that has a lot of uncertainty, there is no way to know precisely how all the factors not under your control will play out. Who hasn't wished they could see into the future? Yet we often have to make a decision before the uncertainty is resolved. For example, imagine a firm deciding whether or not to introduce a new product. The size of the market, the market price, eventual competition, manufacturing costs, and distribution costs all may be uncertain, and all impact the firm's eventual profit. Yet the decision must be made without knowing the outcomes of each of these uncertainties. Worse, because uncertainty clouds the future, as a decision maker one may have to "play the odds," something many people are not accustomed to doing. Or we might try to find an alternative that provides flexibility for adapting as those uncertainties play out.

Decision analysis requires us to think through the uncertainties of our decisions. First, we break each uncertainty down by listing the different outcomes that could occur. Then, for each outcome, we determine both the consequence and the likelihood of that outcome occurring. This is a lot of work, and it is one of the reasons why hard decisions are difficult. But the benefits include knowing which option gives you the best chance at what you want, which option has the most risk, and which uncertainties have the most impact. While understanding uncertainties will not lead to immediate clarity, it can provide decision makers with a richer understanding of the decision problem and help them determine which option best matches their preferences.

Third, a decision maker may be interested in working toward multiple objectives, but progress in one direction may impede progress in others. In such a case, a decision maker must trade off benefits in one area against benefits in another. In the Rice football example, important trade-offs must be made: Are the cost savings from dropping down to Division III worth the potential damage to school pride and alumni relations? Investment decisions usually require us to make a trade-off between risk and return. Decision analysis again provides both a framework and specific tools for dealing with multiple objectives. These tools have the decision maker think about trade-offs in a variety of ways, thereby requiring them to think deeply about what they really want and what might be given up.

Fourth, and finally, a problem may be difficult if different perspectives lead to different conclusions. Or, even from a single perspective, slight changes in

particular inputs may lead to different choices. This source of difficulty is especially pertinent when more than one person is involved in making the decision. Different individuals may look at the problem from different perspectives, or they may disagree on the likelihood or value of the various outcomes. The use of the decision-analysis framework and tools can help sort through and resolve these differences, whether the decision maker is an individual or a group of stakeholders with diverse opinions.

A natural question to ask is whether the effort expended in applying decision analysis is worthwhile. The difficulty in answering this question is that once we have chosen and acted on a decision, we cannot go back and choose a different alternative to see how it would have compared. Thus, it is very hard to know how much difference decision analysis can make. There are many published reports of successful applications of decision analysis, but this evidence is self-reported and testimonial. One study, however, was able to estimate the value of using decision analysis to guide the decision process. An analyst at a large U.S. corporation kept records from 1990 to 1998 on projects in which he used decision analysis techniques. An analysis of these records led Clemen and Kwit (2001) to estimate that the projects were worth about $1 billion to the company. In addition, there were many nonmonetary benefits such as improved communication among project team members and increased commitment to chosen alternatives.

WHY STUDY DECISION ANALYSIS?

The obvious reason for studying decision analysis is that carefully applying its techniques can lead to better decisions. But what is a good decision? A simple answer might be that it is the one that gives a good outcome. This answer, however, confuses the idea of a lucky outcome with a good decision. Suppose an inheritance left us with $100,000 to invest. After carefully considering all the options available and consulting with investment specialists and financial planners, we decide to invest in stocks. Was the investment decision a good one? If we were to answer this question based solely on whether we followed a logical and coherent process that matched our needs with the options, then yes, it was a good decision. If, however, we were to answer this question based solely on the resulting ROI (return on investment), then the quality of the decision would have a lot to do with events beyond our control. For example, if we were unlucky enough to invest in October 2007, when the stock market reached its peak just before plunging into the financial crisis of 2008 to 2009, then most likely we would have done poorly.

All this is to say that good decisions can have unlucky outcomes. Of course, you may prefer to have lucky outcomes rather than make good decisions! Although decision analysis cannot prevent unlucky events, it can help improve the decision you make, in the sense of carefully considering and understanding all the issues. That understanding must include the structure of the problem as well as the uncertainties and trade-offs inherent in the alternatives. You may then improve your chances of enjoying a better outcome; more important, you will be less likely to experience unpleasant surprises in

the form of unlucky outcomes that were either unforeseen or not fully understood. One way to offset the impact of unfortunate events is to employ hedging strategies, but we can only do so if we have first identified the potential pitfalls. Decision analysis provides the structure and tools to better understand all aspects of the problem, and, if necessary, the opportunity to take preemptive corrective actions.

Even though decision analysis opens our eyes to what could happen, we can still run into a brick wall of unfortunate events. This happened to Robert Rubin, Secretary of the Treasury under President Bill Clinton. Early in his career at Goldman Sachs, Rubin took a position that not only proved costly, but his hedge also went the wrong way.

Risk Arbitrage at Goldman Sachs	Robert Rubin was hired in the late sixties to run Goldman Sachs' fabled risk-arbitrage department, which had annual profits in the millions. Essentially, risk arbitrage amounts to buying securities whose prices might change in the near future due to some event, such as a merger or bankruptcy. In this example, Becton Dickinson, a medical equipment manufacturer, announced a friendly takeover of Univis, an eyeglass maker. A share of Univis was selling for $24, and if the merger went through it would be worth $33.50. The decision to engage in risk arbitrage involved intensive research into the companies to determine the odds of the merger happening, the amount of money to be made if it did occur, and the amount put at risk if the deal fell apart. Research involved not only examining the financial reports of each company, but also making personal judgments about the future fit of the two companies, the trustworthiness of the executives, and a general sense of the proposed deal. After all this careful and sophisticated analysis, Goldman Sachs did invest, but after unfavorable earnings by Univis, Becton Dickinson pulled out and Goldman Sachs lost $675,000—more money than they made on any other arbitrage deal that year! Even the hedge Rubin used to protect against loses backfired causing deeper loses.

Was Rubin's decision to invest bad? Rubin states: "While the result may have been bad, the investment decision wasn't necessarily wrong. After a deal broke up, we'd always reexamine it, looking for clues we might have missed. But even a large and painful loss didn't mean that we misjudged anything. As with any actuarial business, the essence of [risk-]arbitrage is that if you calculate the odds correctly, you will make money on the majority of the deals and on the sum total of all your deals." (Rubin and Weisberg, 2003, p. 46).

The preceding discussion suggests that decision analysis allows people to make effective decisions more consistently. This idea itself warrants discussion. Decision analysis is intended to help people deal with *difficult* decisions. It is a "prescriptive approach designed for normally intelligent people who want to think hard and systematically about some important real problems" (Keeney and Raiffa 1976, p. vii).

This prescriptive view is the most appropriate way to think about decision analysis. It gets across the idea that although we are not perfect decision

makers, we can do better through using more structure and guidance. We will see that decision analysis is not an idealized theory designed for superrational and omniscient beings. Nor does it describe how people actually make decisions. In fact, ample experimental evidence from psychology shows that people generally do not process information and make decisions in ways that are consistent with the decision-analysis approach. If they did, there would be no need for decision analysis. Based on fundamental principles, and informed by knowledge of human frailties in judgment and decision making, decision analysis offers guidance to the average person working on a hard decision.

Although decision analysis provides structure and guidance for systematic thinking in difficult situations, it does not claim to produce an alternative that must be blindly accepted. Indeed, after the hard thinking that decision analysis fosters, there should be no need for blind acceptance; the decision maker should understand the situation thoroughly. Instead of providing solutions, decision analysis is perhaps best thought of as simply an information source, providing insights about the situation, uncertainties, objectives, and trade-offs, and possibly yielding a recommended course of action. Thus, decision analysis does not usurp the decision maker's job. According to author Derek W. Bunn

> *"The basic presumption of decision analysis is not at all to replace the decision maker's intuition, to relieve him or her of the obligations in facing the problem, or to be, worst of all, a competitor to the decision maker's personal style of analysis, but to complement, augment, and generally work alongside the decision maker in exemplifying the nature of the problem. Ultimately, it is of most value if the decision maker has actually learned something about the problem and his or her own decision-making attitude through the exercise."* (Bunn 1984, p. 8)

We have been discussing decision analysis as if it were always used to help an individual make a decision. Indeed, this is what it is designed for, but its techniques have many other uses. For example, one might use decision-analysis methods to solve complicated inference problems (i.e., answering questions such as "What conclusions can be drawn from the available evidence?"). Structuring a decision problem may be useful for understanding its precise nature, for generating alternative courses of action, and for identifying important objectives and trade-offs. Understanding trade-offs can be crucial for making progress in negotiation settings. Finally, decision analysis can be used to justify why a previously chosen action was appropriate.

SUBJECTIVE JUDGMENTS AND DECISION MAKING

Clearly, a decision maker's beliefs and personal judgments should be part of the decision process. Even in situations where hard data are available, personal judgments and individual attitudes about risk are important inputs for decision analysis. For example, Robert Rubin used both the financial reports and personal judgments in all his risk-arbitrage deals. It will become clear through this text that thinking hard and systematically about important aspects of a decision naturally help us discover and develop these judgments.

Managers and policy makers frequently complain that analytical procedures from management science and operations research ignore subjective judgments. Such procedures often purport to generate "optimal" actions on the basis of purely objective inputs. But the decision-analysis approach allows the inclusion of subjective judgments. In fact, decision analysis *requires* personal judgments; they are important ingredients for making good decisions.

At the same time, it is important to realize that human beings are imperfect information processors. Personal insights about uncertainty and preferences can be both limited and misleading, even when the individual making the judgments is completely confident. (In fact, we will see that one of our most common pitfalls is overconfidence.) An awareness of human cognitive limitations is critical in developing the necessary judgmental inputs, and a decision maker who ignores these problems can magnify rather than adjust for human frailties.

Much current psychological research has a direct bearing on the practice of decision-analysis techniques. In the chapters that follow, many of the results from this research will be discussed and related to decision-analysis techniques. The spirit of the discussion is that understanding the problems people face and carefully applying decision-analysis techniques can lead to better judgments and improved decisions.
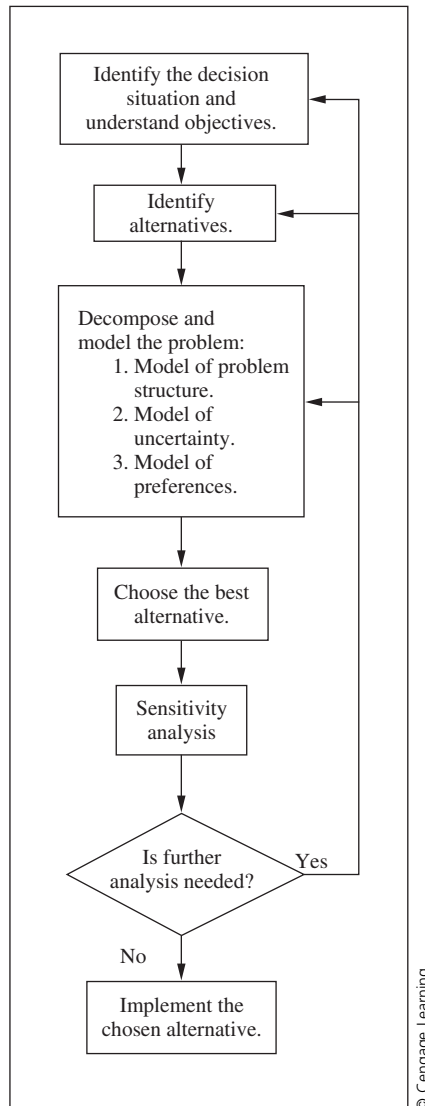
THE DECISION ANALYSIS PROCESS

Figure 1.1 shows a flowchart for the decision analysis process. The first step is for the decision maker to identify the decision situation and to understand his or her objectives in that situation. Although we usually do not have trouble finding decisions to make or problems to solve, we do sometimes have trouble identifying the exact problem, and thus we sometimes treat the wrong problem. Careful identification of the decision at hand is always important. Sometimes a surface problem hides the real issue. Hypothetically, perhaps the issue for Rice's board is not the $4 million deficit, but regaining control over an ever increasingly powerful athletic program that has been flouting school policies.

Understanding one's objectives in a decision situation is also an important first step and involves some introspection. What is important? What are the objectives? Minimizing cost? Maximizing profit or market share? What about minimizing risks? Does risk mean the chance of a monetary loss, or does it refer to conditions potentially damaging to health and the environment? One must develop a clear understanding of the crucial objectives in a decision situation before much more can be accomplished. In the next step, knowledge of objectives can help in identifying alternatives, and beyond that the objectives indicate how outcomes must be measured and what kinds of uncertainties should be considered in the analysis.

Many authors argue that the first step is to identify the problem and then figure out the appropriate objectives to be used in addressing the problem. But Keeney (1992) argues the opposite; it is far better, he claims, to spend a lot of effort understanding one's central values and objectives, and then looking for ways—decision opportunities—to achieve those objectives. The debate

FIGURE **1.1**
A decision analysis
process flowchart.

A decision analysis process flowchart.

Flowchart:
- Identify the decision situation and understand objectives.
- Identify alternatives.
- Decompose and model the problem:
  1. Model of problem structure.
  2. Model of uncertainty.
  3. Model of preferences.
- Choose the best alternative.
- Sensitivity analysis
- Is further analysis needed? — Yes / No
- Implement the chosen alternative.

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notwithstanding, the fact is that decisions come in many forms. Sometimes we are lucky enough to shape our decision-making future in the way Keeney suggests, and other times we find ourselves in difficult, unanticipated situations. In either case, establishing the precise nature of the decision situation (which we will call the *decision context*) goes hand-in-hand with identifying and understanding one's objectives in that situation.

With the decision situation and pertinent objectives established, we turn to the discovery and creation of alternatives. Often a careful examination and analysis of objectives can reveal alternatives that were not obvious at the outset. This is an important benefit of a decision analysis approach. In